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黄耆属簇毛黄耆亚属生物地理学研究*

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摘要：簇毛黄耆亚属的种类主要沿亚洲的“山链”分布，即横断山，喜马拉雅，查谟和克什米尔，帕米尔－阿赖，兴都库什和苏莱曼山脉，表达了东亚、西亚和中亚的植物区系地理关系。本文基于亚属的分布式样，对其8个分布区进行了分析生物地理学中的成分分析。结果表明，这8个分布区可划分为4类，即1）华北－东北；2）横断山和西藏；3）西喜马拉雅，西巴基斯坦，塔吉克斯坦；4）内蒙古－新疆。在本亚属的分布式样中，有两个地理“结点”，即横断山和西喜马拉雅，后者主要指克什米尔。推断地理上的衍进方向是由东向西发展，喜马拉雅是连接东西分布的通道。

关键词：簇毛黄耆亚属；豆科；成分分析；分布式样；分布区关系
中图分类号：Q 948 **文献标识码：**A **文章编号：**0253－2700(2003)01－0025－08

Biogeography of *Astragalus* Subgenus Pogonophace (Leguminosae)*

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Abstract: The distribution of *Astragalus* subgenus Pogonophace, along the Asian mountain chains namely Hengduan Mountains, Himalayas, Jammu and Kashmir, Pamir-Alai, Hindukush and Sulaiman, shows the floristic relationships of the East Asia, West Asia and Central Asia. On the basis of the phylogenetic analysis, the distribution pattern of Pogonophace was studied by means of COMPONENT analysis of the analytical biogeography. The eight distribution areas of Pogonophace were treated as the operational biogeographical units. The results indicated that the eight areas could be classified into four types, i. e., 1) North China-Northeast China, 2) Hengduan Mountains and Xizang (Tibet), 3) Western Himalayas, Western Pakistan, and Middle Asia (Tajikistan), and 4) Inner Mongolia and Xinjiang belonging to Central Asia. Two phytogeographical nodes i. e. Hengduan Mountains and Western Himalayas ad hoc Kashmir were suggested. The area progressive direction was inferred to be from eastern to western distribution areas, and Himalayas was a corridor jointing the eastern and western distribution areas.

Key words: Pogonophace; Leguminosae; Component analysis; Distribution pattern; Area relationship

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Historical biogeography study the distribution pattern of organism and explain the why of the distribution pattern. There are so far many standard methods and procedures (Nelson & Platnick, 1981; Humphries & Parenti, 1986, 1999; Myers & Giller, 1988). The distribution pattern of the subgenus *Astragalus* Pogonophace is analyzed with basing on the phylogeny in this paper.

The phylogeny of subgenus Pogonophace was studied (Zhang, 2002). The results showed that forty-nine species and varieties were classified into nine sections (Zhang, 2002). There are three distribution centers of *Astragalus* in the world, namely Iran-Turkey center, Himalayan center and western American Plain center (Sanderson, 1991). The Himalayan center in fact occurs in the alpine zone of Hengduan Mountains and along Himalayas especially eastern Himalayas (Baker, 1876; Fu *et al*. 1993; Zhang, 2000). Pogonophace, with distribution center in Hengduan Mountains (Zhang, 2000), is a typical group to indicating the Himalayan center of *Astragalus*. So historical biogeography of Pogonophace has the significance to *Astragalus*. At the same the time most species of Pogonophace occur in some Asian mountain chains which include Hengduan Mountains, Himalayas, Pamir-Alai, Hindukush and Sulaiman. These mountains are jointing the East Asia, West Asia and Middle Asia flora. Therefore the distribution pattern of Pogonophace is the representative of general distribution pattern of some plant groups.

1 Materials and Methods

Phylogenetic tree The phylogenetic tree resulted from forty-nine species and varieties and thirty-three characters (Zhang, 2002), see Fig. 1. The tree (Zhang, 2002) showed that nine sections were located under itself clade except Sect. Bibracteolati and Sect. Phyllolobium were paraphyletic respectively.

Area Pogonophace species are distributed mainly in Hengduan Mountains and Himalayas and other mountains mentioned above (Ali, 1977; Fu, 1993; Zhang, 2000). According to the distribution pattern of this subgenus and the floristic divisions of China (Wu & Wu, 1996) and the world (Takhtajan, 1986), eight areas are treated as operational objects of Pogonophace biogeography, see Fig. 1. It is necessary to note that Hengduan Mountains consist of eastern Himalayas; Western Himalayas including North India, Jammu and Kashmir, Pamir-Alai, and adjacent region; Western Pakistan comprising eastern Afghan and adjacent region. Central Asia here means southern Tadzhikistan.

Component Analysis In Fig.1, the areas were labeled on the back of species in order to convert the taxon cladogram to the area cladogram. Since some species massed in one area, for example, many species of Sect. Bibracteolati appearing in Hengduan mountains, so resolved cladogram was obtained by deleting some species and using fewer species representing the status in the area. Finally, the resolved cladogram used to do the COMPONENT analysis was as following.

(NC, HD, (XZ, (HD, (XZ, (WP, ((WP, WH), (WP, MA))), ((XZ, WH), ((XZ, WH), ((WH, WP), ((WP, MA), ((WH, WP), (XJ, IM))))))))))).

According to assumption 0, Assumption 1 and Assumption 2 (Nelson & Platnick, 1981; Zandee & Roos, 1987), COMPONENT package version 2.0 (Page, 1993) was used to treat the distribution data and find the area cladogram.

2 Results

The area cladograms from the COMPONENT analysis resulted in three area cladograms with three assumptions.

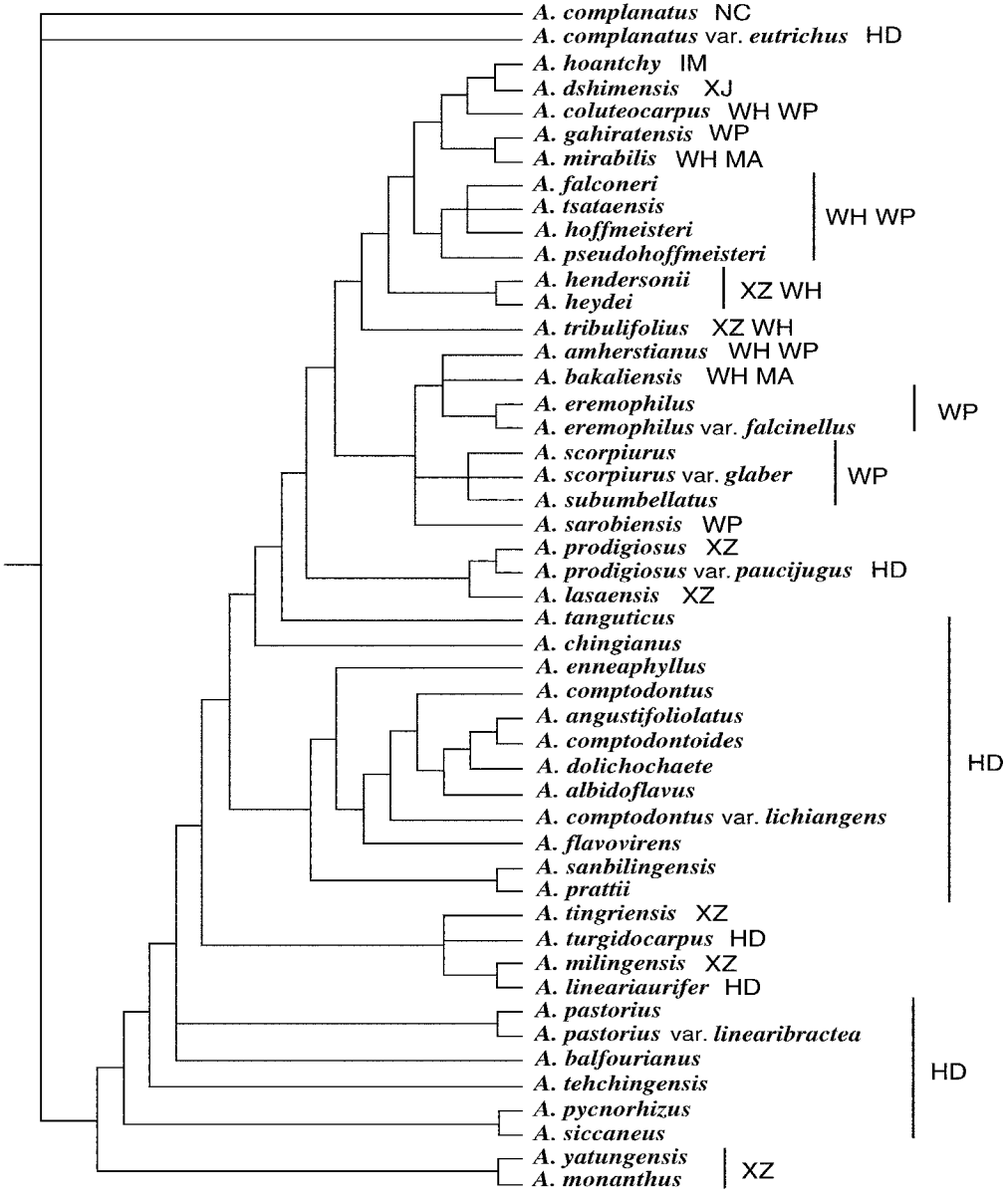

Fig. 1　A taxon cladogram of Pogonophace and taxa distribution used to the Component analysis. NC：North China-Northeast China，HD：Hengduan Mountains，XZ：Xizang (Tibet)，WH：Western Himalayas，WP：Western Pakistan，MA：Middle Asia (Tajikistan)，IM：Inner Mongolia，XJ：Xinjiang.

Assumption 0：One parsimonious tree was generated under Assumption 0 (Fig.2).

Assumption 1：2079 equally most parsimonious trees were produced under Assumption 1，the consensus analyses were by using Strict option，Majority-rule option，Semi-Strict option，Nelson option and Adams option，respectively. But the resulting trees from Strict option，Semi-Strict option and Majority-rule option were same，so there were three area cladograms under Assumption 1 (Fig. 3a-c).

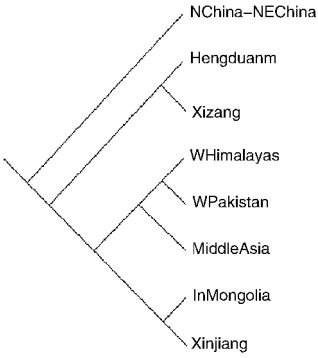

Fig.2 An area cladogram of Pogonophace under Assumption 0 using component analysis based on the taxon cadogram Fig.1. Only one area cladogram from component analysis.

Assumption 2：13 equally most parsimonious trees were produced under Assumption 2, the consensus analysis was also by using Strict option, Majority-rule option, Semi-Strict option, Nelson option and Adams option respectively. Under Assumption 2, the resulting trees from Majority-rule option and Adams option were same. There were four area cladograms under Assumption 2 (Fig. 4a-d).

All above results of the area relationships could be summed in Fig.5.

3 Discussions

Area relationship From the Assumption 0, Assumption 1 and Assumption 2, Inner Mongolia and Xinjiang are sister areas in all area cladograms (Fig. 2 – 4 except Fig. 3a). It is result shown two areas have close area relationship in Pogonophace. In fact in two areas only two related species, *A. hoantchy* and *A. dshimensis* respectively are distributed in. These two species are the only species of Sect. Robusti. Recent experimental systematic studies suggested that this section was isolated from other sections in Pogonophace (Zhang *et al*, 2002；Kang *et al*, 2001).

The results under the Assumption 0 and Assumption 2 showed that Western Himalayas, Western Pakistan and Middle Asia had a close area relationship (Fig. 2 and Fig. 4). Western Himalayas and Western Pakistan had a close relationship since there are some taxa are shared between the two areas. The taxa are Sect. Coluteocarpus comprising only one species *A. coluteocarpus*, Sect. Sesbanella including *A. falconeri*, *A. hoffmeristi* etc., and *A. amherstianus* of Sect. Falcellalus. Because the area Western Pakistan in present paper including eastern Afghan where being arid traits, so Western Himalayas have a relationship with arid Central Asia and West Asia. And its flora was different from that of East Himalayas and Hengduan Mountains being humid traits and belonging to East Asia flora (Wu & Wu, 1996；Takhtajan, 1986). Middle Asia with special to Tajikistan has relation to these two areas since *A. mirabilis* and *A. bakaliensis* adaptive radiation former from Western Pakistan and latter from Western Himalayas.

Hengduan Mountains and Xizang (Tibet) have a close relationship as shown in Fig. 2, because of some species especially Sect. Bibracteolati with an adaptive radiation from Hengduan Mountains to Xizang (Tibet).

In terms of area cladograms especially Assumption 0 (Fig.2) and distributions of species and sections in Pogonophace, the areas could been classified into four regions as follows. 1) North China-Northeast China, 2) Hengduan Mountains and Xizang (Tibet), 3) Western Himalayas, Western Pakistan, and Middle Asia Tajikistan, 4) Inner Mongolia and Xinjiang belonging to Central Asia (Grubov, 1999).

Area progressive direction The area progressive direction under the Assumption 0 and Assumption 2 shown in Fig. 2 and Fig. 4, respectively, was from North China-Northeast China and Hengduan Mountains which two areas located at the deep position of the area cladograms. Under three

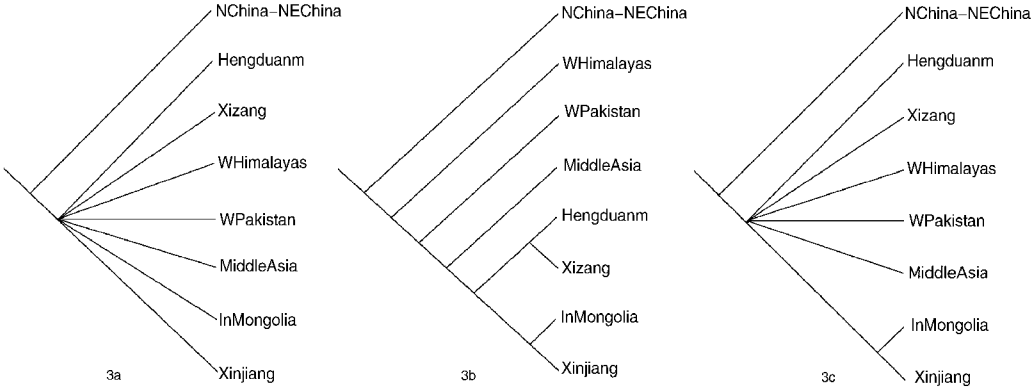

Fig. 3　An area cladograms of Pogonophace under Assumption 1 using component analysis based on the taxon cadogram Fig. 1. 2079 equal parsimonious area cladograms obtained from component analysis. Then the consensus area caldograms were been obtained by using different options. Fig 3a resulted from a same area cladogram of three options, which were Strict, Majority-rule and semi-strict options. Fig 3b resulted from Nelson option. Fig 3c resulted from Adams option.

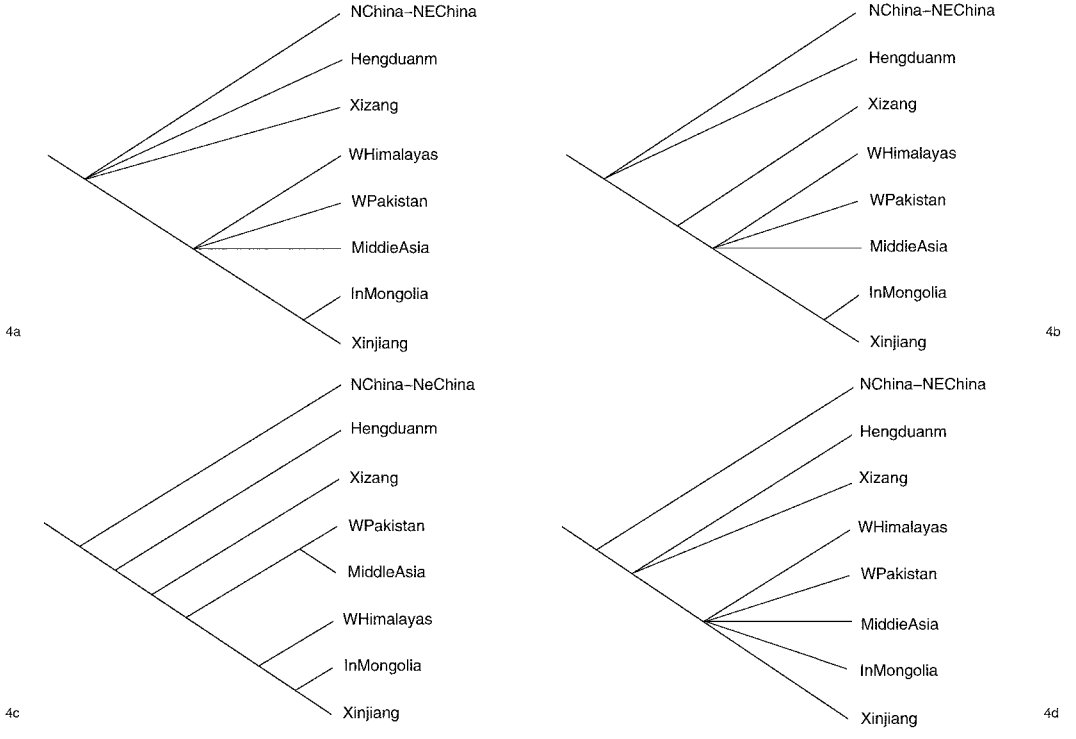

Fig. 4　An area cladograms of Pogonophace under Assumption 2 using component analysis based on the taxon cadogram Fig. 1. 13 equal parsimonious area cladograms obtained from component analysis. Then the consensus area cladograms were been obtained by using different options. Fig. 4a resulted from Strict option. Fig. 4b resulted from a same area cladogram of two options, which were Majority-rule and Adams options. Fig. 4c resulted from Nelson option. Fig. 4d resulted from Semi-Strict option.

Assumptions area cladograms Fig.2, Fig.3, Fig.4c and Fig.4d, the deep area was North China-Northeast China. Under the Assumption 2 Fig.4a, North China-Northeast China, Hengduan Mountains and Xizang (Tibet) were paratactically placed at deep position of area cladogram. North China-Northeast China was all at the deep positions of area cladograms except Fig.4a and Fig.4b. So three areas, North China-Northeast China, Hengduan Mountains and Xizang (Tibet) were certainly the ancestral areas especially North China-Northeast China, and apparently, area progressive direction was orderly from these three areas to other areas in Pogonophace. These results mean that the area progressive direction was from the east to the west of Pogonophace distribution areas. Himalayas was a corridor linking the eastern and western distribution areas, see Fig.5.

Two phytogeographical nodes An area could be called the phytogeographical node meant that area have the rich taxa and the connections with its adjacent areas. In the present paper two phytogeographical nodes for Pogonophace were Hengduan Mountains and Western Himalayas ad hoc Kashmir, see Fig.5.

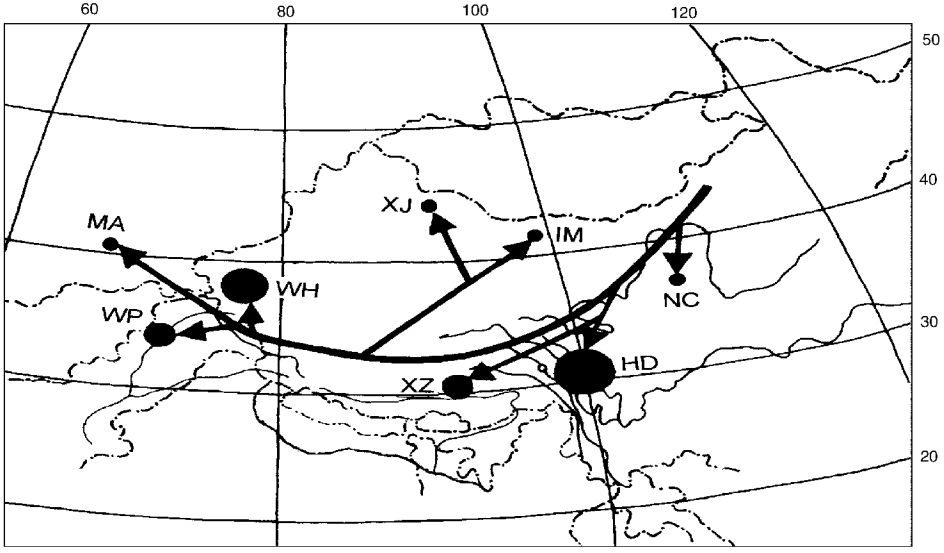

Fig. 5 A summary of the area relationships, progressive direction and phytogeographical nodes in Pogonophace distribution.

Hengduan Mountains, was suggested to be the distribution center, differentiation center and endemic center of Pogonophace (Zhang, 2000). The range of this area consists of western Sichuan, northwestern Yunnan and eastern Xizang (Tibet) provinces in China. Hengduan Mountains have had an ancient geological history and complex temporal physical environments, particular high mountains and deep narrow gorge, and ecological factors humid and cold (Zhao, 1985). There is a rich flora here and has been inferred to be the origin place of North Temperate flora (Li, 1948; Wu, 1979, 1988; Wang, 1989; Wang, 1992). For Pogonophace Hengduan Mountains have the conjunction to North China in couple of vicariance species *A. complanatus* and its variety var. *entrichus*, the former

occur in North China-Northeast China and latter in Hengduan Mountains. Some species distributing in Hengduan Mountains especially of Sect. Bibracteolati such as *A. tanguticus*, *A. milingensis*, *A. prodigiosus*, *A. pycnorhizus* etc., could adaptively radiated to Xizang (Tibet), which expressed that the area relationship between Hengduan Mountains and westward Xizang (Tibet). So Hengduan Mountains could been considered the evolutionary node in Pogonophace.

Another important phytogeographical node in Pogonophace was Western Himalayas ad hoc Kashmir. In this paper Western Himalayas consist of North India, Jammu and Kashmir, Pamir-Alai, and adjacent region. Kashmir was the density place of Pogonophace species. In Kashmir there are several species belonging to some different sections of Pogonophace, and these species occurring in Western Himalayas and adjancent areas, Western Pakistan, Pamir-Alai, such as Sect. Coluteocarpus comprising only one species *A. coluteocarpus* appearing in Western Himalayas and Western Pakistan i. e. Kashmir, Pamir-Alai, North India, West Pakistan and Northeast Afghan, Sect. Sesbanella including *A. falconeri* in Kashmir, western Xizang (Tibet), western Pakistan, *A. hoffmeristi* in Kashmir, western Xizang (Tibet), and northern India. *A. amherstianus* of Sect. Falcellalus appearing in Kashmir, North India, West Pakistan and Northeast Afghan. *A. heydei* and *A. hendersonii* belonging to Sect. Trichostylus are distributing in Kashmir and western Xizang (Tibet) along Himalayas. In conclusion, four sections of Pogonophace are distributed in Western Himalayas ad hoc Kashmir, so this area could be proposed as a phytogeographical node to this subgenus.

Phytogeographical significance of Pogonophace With a typical distribution pattern, Pogonophace is at the junctions among the floras of the East Asia, West Asia and Central Asia. The mountain chains namely Hengduan Mountains, Himalayas, Jammu and Kashmir, Pamir-Alai, Hindukush, and Sulaiman, formed the main framework of the distribution pattern. The area relationships in this subgenus could be proposed using the area classification and the two phytogeographical nodes as mentioned above. There are some similar relations but also dissimilarity among/between floras of the East Asia, West Asia and Central Asia. The particular endemism in this subgenus could be considered as an important factor (Zhang, 2000).

There were many groups illustrating that Himalayas was the corridor connecting the floras of the East Asia, West Asia and Central Asia (Kitamura, 1963; Tabata, 1988; Wang, 1992). Maybe some groups were continuous along Himalayas or some were disjunct between Western and Eastern Himalayas caused by the Great Himalayas uplifting (Tabata, 1988). Pogonophace, an arid and cold adaptive group, were continuous mainly on "Tibetan side" (Tabata, 1988) and Xizang (Tibet) Plateau with some continuous vicariance event, for example, the related species *A. tanguticus* and *A. tribulifolius*, former appearing in Hengduan Mountains and latter in western Xizang (Tibet) Plateau and Western Himalayas. *A. heydei*, *A. hendersonii*, *A. coluteocarpus* distributed Western Himalayas and western Xizang (Tibet) along Himalayas.

The progressive direction or adaptive radiation of species was inferred from eastern to western areas mainly along Himalayas. The results were consistent with the adaptive radiation of many distribution patterns of East Asia flora along Himalayas (Wang, 1992), such as *Caragana* (Kamarov, 1945; Zhang, 1997), but there were also some groups especially Mediterranean floristic elements, have had different migration direction from western Himalayas to eastern Himalayas.

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